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CHAPTER 3.8
IMPACT- OR COLD-EXTRUDED PARTS

John L. Everhart, P.E.

Metallurgical Engineer
Westfield, New Jersey

THE PROCESS

The process is generally called *impact extrusion* by the producers of nonferrous parts and *cold extrusion* by those producing ferrous parts, but no distinction will be made between these terms in this text. Impact extrusion is a chipless method that involves forcing a metal to flow through an orifice by compressive stressing and thereby forming a part of the desired shape. The operation is shown schematically in Figs. 3.8.1 and 3.8.2. Figure 3.8.1 represents backward extrusion; Fig. 3.8.2, forward extrusion. For the production of certain parts, combined backward and forward extrusion is used.

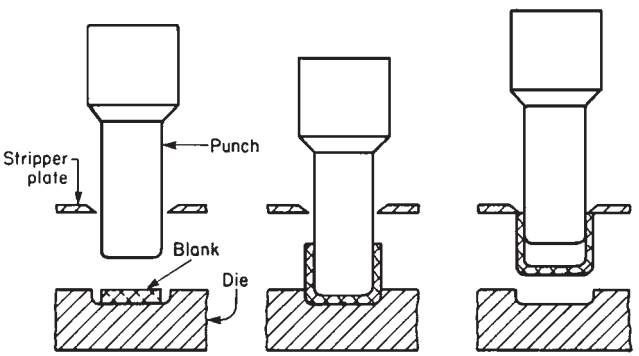

FIGURE 3.8.1 Backward extrusion. Blank in die chamber (*left*); extrusion of shell (*center*); stripping shell (*right*).

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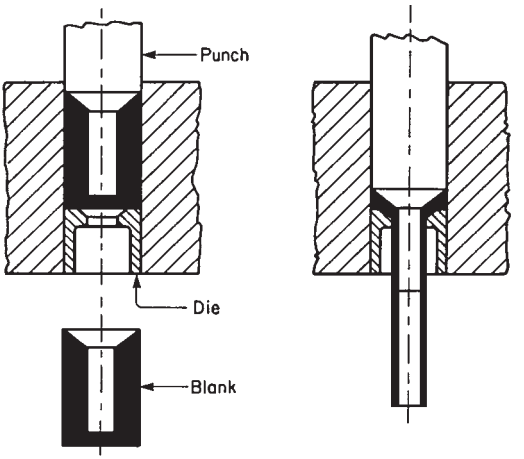

FIGURE 3.8.2 Forward extrusion. Blank (*lower left*); blank in die chamber (*upper left*); extrusion of shell (*right*).

Backward Extrusion

In backward extrusion, a blank of metal to be extruded is placed in the cavity of a die and compressed by a punch. The metal is forced to flow through the annular opening between punch and die, and it rises along the punch. The thickness of the base is determined by the press stroke and is independent of the wall thickness.

Forward Extrusion

In forward extrusion, a blank is placed in the cavity of a die having a restriction. The punch fits so closely that metal cannot flow between it and the die walls. As the punch descends, it compresses the blank and causes it to extrude through the orifice formed by the projection on the die and the nose of the punch.

Blanks for forward extrusion are generally preformed to the contour necessary to obtain the desired configuration of the extruded part. Forward extrusion requires less power than backward extrusion for the production of parts of equivalent size, and smaller presses can be used. Because part length is practically independent of punch length, a short, stocky punch can be used. However, secondary tooling may be required to permit removal of the extruded part from the die, and this requirement will increase the cost of tooling over that required for a simple backward extrusion.

With forward extrusion, the shape of the blank plays a role in shaping the part. In some cases, several different parts can be produced with the same set of tools merely by changing the shape of the blank.

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IMPACT- OR COLD-EXTRUDED PARTS

Combined Extrusion

Backward and forward extrusion can be used simultaneously to form parts. This procedure is followed frequently.

TYPICAL CHARACTERISTICS OF IMPACT-EXTRUDED PARTS

Parts produced by impact extrusion often require only trimming to length after forming. In other cases, operations of a secondary nature are reduced from those required with several competing processes. In addition, certain components that cannot be made by other methods can be formed.

The process can be applied to produce parts from a wide variety of metallic materials. In commercial production are parts made from aluminum, copper, lead, magnesium, tin, zinc, and their alloys and from various steels.

The use of impact extrusion should be considered when

1. The part length is greater than 2 or 3 times the diameter.
2. The part is hollow, with one end closed or partially closed.
3. The part would require considerable machining if produced by another method.
4. The base must be thicker than the sidewalls.
5. Zero draft is desired in the sidewalls.
6. Redesign will permit use of a one-piece part instead of an assembly.
7. Large-quantity production is planned.

Impact extrusion should probably not be considered if

1. The part can be readily made on a screw machine.
2. Only a few parts are required.
3. The part is asymmetrical, with a length greater than 3 to 4 times the diameter.
4. The bottom must be flat from edge to edge.

Backward extrusion can be used to produce a wide variety of shells with circular, oval, square, rectangular, and other polygonal cross sections. In general, the sidewalls must be perpendicular to the base to permit flow during extrusion, but vertical ribs can be formed on the internal and external walls. Multiwall shells also can be formed.

Advantages of backward extrusion include simplicity of tooling and ease of removal of the shell after forming. However, the process has limitations. The punch must be long enough to accommodate the entire length of the shell, plus an allowance for trimming, and a long-stroke press is frequently required. There is therefore a limit to the length of part that can be formed by this procedure. Further, in the extrusion of long shells the punch has a tendency to float, and this tendency is increased by play in the moving head of the press. As a result, there is some difficulty in maintaining uniform wall thicknesses in long extrusions.

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Forward extrusion can be used to produce open- or closed-end tubes. The bottom of a closed-end tube can be of the same thickness as the sidewalls or heavier. Sidewalls can be parallel or tapered, and parts can be produced with fillets. (*Note:* Forward extrusion in this chapter applies to the production of discrete pairs that normally have one end closed. Chapter 3.1, "Metal Extrusions," covers the production of long pieces of constant cross section made with a closely related process.)

Since a true alignment of punch and die is ensured, tolerances can be held more closely with forward extrusion than is possible with backward extrusion of long shells. However, the shapes that can be produced by forward extrusion are more limited than those which can be formed by backward extrusion. In particular, the base of the forward-extruded part must be plain because there is no forging action against the die bottom. In general, the forward-extruded parts produced are solid rods or tubular forms. The tubes can be open or closed and have parallel or tapered walls, and the wall thickness of the tapered end can be varied.

Figure 3.8.3 illustrates typical impact-extruded parts.

FIGURE 3.8.3 A variety of typical impact-extruded parts.

Combined Extrusions

Most of the shapes produced by backward extrusion can have forward-extruded rods or tubes formed at the same time. (See Fig. 3.8.4.) The two sections of such parts can have the same or different cross-sectional areas and different wall thicknesses that can have the same or different shapes. A cup having a square cross section can be backward-extruded at the same time as a tube having a circular cross section is being forward-extruded. Tubes can be extruded in both directions from a flanged portion. (See Fig. 3.8.5.) Combined extrusion often can be used to produce a part that can replace an assembly.

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IMPACT- OR COLD-EXTRUDED PARTS

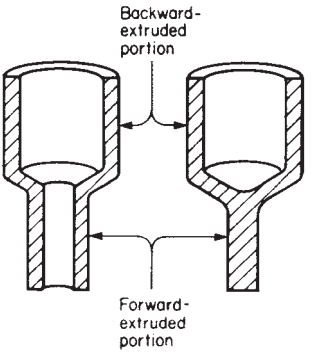

FIGURE 3.8.4 Combined extrusions.

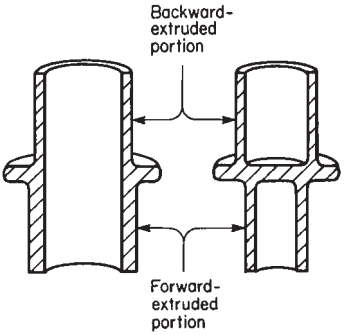

FIGURE 3.8.5 Combined extrusions from a flange.

ECONOMIC PRODUCTION QUANTITIES

Generally, impact extrusion is a mass-production operation. For parts of small size, 1000 pieces per month might be uneconomical, while 10,000 or more pieces would be desirable. With larger parts, 1000 pieces per month might be sufficient for economical operations. Going to the other extreme, a producer of aluminum parts states that 50,000 is an economical lot size for automatic production. The same producer, however, notes that if tooling is available, any lot size is practical. For steel, suggested minimum economic production quantities are

10,000 for parts weighing 1 to 2 g (0.035 to 0.07 oz)
5000 for parts weighing 2 to 500 g (0.07 oz to 1.1 lb)
3000 for parts weighing over 500 g (1.1 lb)

SUITABLE MATERIALS

Components are produced commercially from aluminum, copper, lead, magnesium, tin, zinc, and their alloys and from various steels. Certain less common materials (e.g., zirconium alloys for nuclear applications) are employed for specialty products.

In the nonferrous-alloy systems, the pure metal requires a lower extrusion pressure than the alloys, and therefore, greater reductions of area can be made with the pure metals than with the alloys. For example, the practical minimum wall thickness for backward extrusion of a 1-in-diameter shell is 0.010 in using commercial aluminum and 0.040 in for the high-strength 7075 (A97075) alloy. In the steels, the carbon steels permit lower extrusion pressures than the alloy steels, but structure also plays a significant role.

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Aluminum

The selection of a particular alloy depends on the properties required. Alloys such as 1100 (A91100) and 3003 (A93003), which are strain-hardenable and cannot be heat-treated for property improvement, are used to meet moderate-strength requirements. The heat-treatable alloys 6061 (A96061), 6066 (A96066), and 6070 (A96070) are used when greater strength or improved machinability is required. The heat-treatable alloys 2014 (A92014), 7001 (A97001), and 7075 (A97075) are used when the highest possible strengths obtainable in aluminum alloys are required.

Copper

Because of its excellent ductility and high electrical conductivity, oxygen-free copper is the most widely used of the copper-base materials, but ETP copper and zirconium copper are also used for components requiring high electrical or thermal conductivity. Brasses, nickel silvers, and copper-nickel alloys are also used for impact-extruded parts, their selection being based usually on strength requirements and corrosion resistance. These materials are all strain-hardenable, with the exception of zirconium copper, and cannot be improved by heat treatment.

Lead and Tin

These materials are considered together because their major field of application is specialized. They are used mainly for collapsible tubes. Lead and tin are the most readily impact-extruded metals. Unalloyed lead and tin, lead-antimony to 2 percent antimony, and tin-copper to 1 percent copper are used.

Magnesium

The impact extrusion of magnesium differs from that of aluminum in one respect. Because the structure of magnesium is such that it cannot be worked readily in the cold, the blanks must be warmed. Generally, temperatures in the range of 230 to 370°C (450 to 700°F) are used. As a result, the parts are not strain-hardened. Typical alloys used for impact-extruded parts are AZ31B (M11311), AZ61A (M11611), AZ80A (M11800), and ZK60A (M16600).

Zinc

Pure and commercial zincs have been impact-extruded for quite a few years, and a few alloys such as zinc-cadmium (0.6 percent Cd) and zinc-copper (up to 1 percent Cu) are also employed. Generally, the blanks are warmed, and there is no strain hardening as the result of extrusion.

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Steels

Low-carbon steels can be extruded more readily than steels of higher carbon content, and the alloying elements generally must be held to relatively low values, although some high-alloy steels have been extruded successfully. Low-carbon and some low-alloy steels can be processed in the stress-relieved normalized condition for some shapes. The higher-carbon and steel-alloy steels require complete spheroidization for successful cold extrusion, particularly for backward extrusion. Recently, boron-containing steels have been developed for cold-forming operations. They do not increase the extrusion pressure, and they permit the use of relatively low-carbon steels to achieve properties that can be met with non-boron-containing steels only at higher carbon contents.

Steels being used commercially for cold extrusion include

Carbon steels 1006–1050 (GI0060–G10500)

Manganese steels 1330–1345 (GI3300–G13450)

Molybdenum steels 4012–4047 (G40120–G40470)

Chromium-molybdenum steels 4118–4140 (G41180–G41400)

Manganese-molybdenum steels 4615–4626 (G46150–G46260)

Chromium steels 5115–5140 (G51150–G51400)

Nickel-chromium-molybdenum steels 8615–8630 (G86150–G86300)

DESIGN RECOMMENDATIONS FOR BACKWARD EXTRUSION

Symmetry

To minimize tooling deflection, it is desirable to aim for symmetry in the design of parts unless they are quite short in relation to their diameter. Figure 3.8.6 shows examples of good and poor design. Parts on the right can be produced with close tolerances and with a minimum of lateral movement of the punch. In producing parts such as those shown on the left, the forces tend to be off center and lateral movement can occur. One way to minimize floating of the punch is to include a small recess in the part design (see Fig. 3.8.7); the point on the punch required to produce this recess aids in maintaining alignment.

Flow

In backward extrusion, the metal is forced to flow through an orifice to form the sidewalls. Parts must therefore be designed to prevent restrictions to flow:

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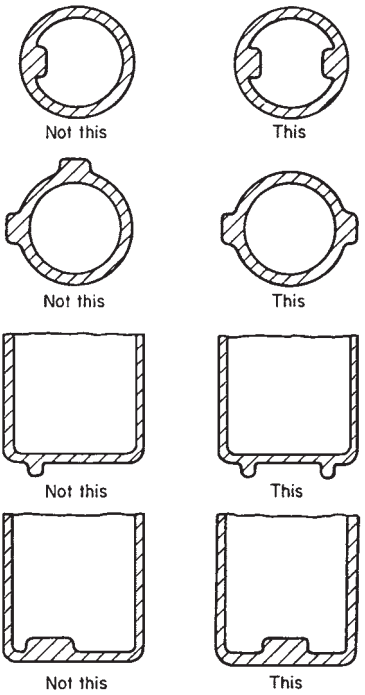

FIGURE 3.8.6 Impact-extruded parts should be symmetrical to avoid lateral movement of tooling punches and unequal wall thickness.

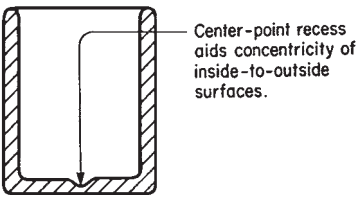

FIGURE 3.8.7 A small recess in the bottom of the part minimizes floating of the punch and thereby helps ensure uniform wall thickness.

1. Assist flow by incorporating suitable inclined bottom surfaces near the sidewalls and by rounding the outside corners of the part as shown in Figs. 3.8.8*b* and 3.8.9. Note that the inside bottom radius should be as small as possible.
2. To ensure minimum restriction to flow, whenever possible, use a design that includes a bottom angle approaching 120°. (See Figs. 3.8.8*d* and *e*.)

Bottom Design

The bottom of a backward-extruded part can be thicker than the walls or of equal thickness. However, a thicker bottom can aid in metal flow, and some authorities recommend that the bottom-wall thickness should be at least 15 percent greater than that of the sidewalls. (See Fig, 3.8.9.) The thickest area should be at the base of the sidewalls, but it can be tapered to be thinner at the center.

The inside bottom surface of a part should not be completely flat but can be flat for approximately 80 percent of the inside diameter. (See Fig. 3.8.9.) Spherical bottoms should be avoided, especially in long shapes; use an angular bottom instead, as shown in Fig. 3.8.8*d*. Bottom cross sections can be circular, oval, square, rectangular, or of any other regular polygonal shape. They also can be irregular provided they are symmetrical. However, circular cross sections are preferable. When a nozzlelike projection

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IMPACT- OR COLD-EXTRUDED PARTS

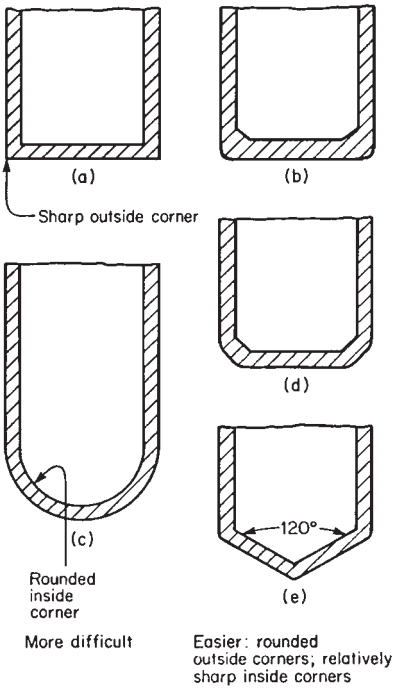

FIGURE 3.8.8 Inclined bottom surfaces and rounded outside corners assist metal flow in backward extrusion.

is required on the bottom, ample taper should be allowed on both inside and outside. This strengthens the punch extension that forms the hole inside the nozzle and helps strip the extruded part from the punch.

Length-Diameter Ratio

The length of parts that can be formed by backward extrusion is limited by the column strength of the punch and also depends on the material being extruded. For commercial operations in general, the length of an aluminum part should not be greater than 6 to 10 times the diameter; for steel parts, the length should be more limited, probably 3 to 4 times the diameter. (See Table 3.8.1.) The greater the length, the greater is the tendency of the punch to float and consequently the greater the variation in wall thickness to be expected.

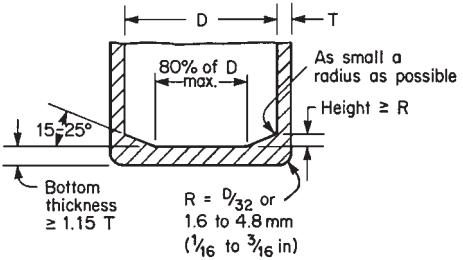

FIGURE 3.8.9 Details of the recommended bottom design for backward extrusion.

Draft

No draft is required on the walls of backward extrusions.

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TABLE 3.8.1 Practical Length-Diameter Ratios for Backward Extrusion

Aluminum and softer aluminum alloys	8:1 to 10:1
Harder aluminum alloys	5:1 to 7:1
Copper and copper alloys	3:1 to 5:1
Magnesium and magnesium alloys	6:1 to 9:1
Zinc and zinc alloys	4:1 to 6:1
Carbon steels	3:1 to 4:1
Low-alloy steels	2:1 to 3:1

Ribs

Longitudinal ribs can be produced on either the outside or the inside of the sidewalls. External ribs need not be spaced equally but should be arranged in a symmetrical design.

External ribs can have heights up to 2 times the wall thickness, but 1 times wall thickness is preferable. (See Fig. 3.8.10.) Internal ribs can run the full length of the shell or be designed to terminate at a desired distance from the closed end. The maximum recommended height of internal ribs is 3 times wall thickness. (See Fig. 3.8.11.)

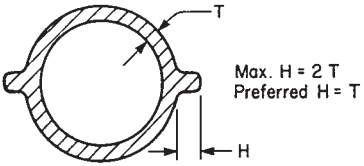

FIGURE 3.8.10 The maximum recommended height of external ribs is 2 times wall thickness, but 1 times wall thickness is preferred.

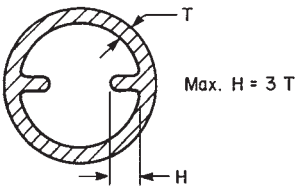

FIGURE 3.8.11 The maximum recommended height of internal ribs is 3 times wall thickness.

Bosses

External and internal bosses in the axial direction can be produced as integral parts of the design. They can be produced on the same shell, and they can be of the same or of different diameters and lengths and of different cross sections. External bosses can be produced in any size up to the diameter of the shell and can be solid or hollow. Solid bosses can be of almost any symmetrical shape. Internal bosses can be longer than the sidewalls. Cross sections can be round, oval, square, or of other regular configurations.

The diameter of an inside boss should be not more than one-fourth the diameter of the shell. The preferred location for bosses is on the axis of a part. If not coaxial, bosses should be in a symmetrical arrangement; otherwise, metal will tend to flow unevenly. Avoid sharp edges and corners on bosses, for they make it difficult for the metal to flow properly.

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TABLE 3.8.2 Practical Minimum Wall Thicknesses for Backward-Extruded Aluminum Parts

Outside diameter, mm (in)	Alloy and wall thickness, mm (in)			
	1100 (A91100)	6061 (A96061)	2014 (A92014)	7075 (A97075)
25 (1)	0.25 (0.010)	0.38 (0.015)	0.90 (0.035)	1.0 (0.040)
50 (2)	0.50 (0.020)	0.76(0.030)	1.8 (0.070)	2.0 (0.080)
75 (3)	0.76 (0.030)	1.1 (0.045)	2.7 (0.105)	3.0 (0.120)
100 (4)	1.0 (0.040)	1.5 (0.060)	3.6 (0.140)	4.0 (0.160)
125 (5)	1.3 (0.050)	1.9 (0.075)	4.4 (0.175)	5.0 (0.200)
150 (6)	1.5 (0.060)	2.3 (0.090)	5.3 (0.210)	6.0 (0.240)
175 (7)	1.9 (0.075)	2.8 (0.110)	6.2 (0.245)	7.0 (0.280)
200 (8)	2.5 (0.100)	3.3 (0.130)	7.0 (0.280)	8.0 (0.320)
225 (9)	2.8 (0.110)	3.7 (0.145)	8.0 (0.320)	9.0 (0.360)
250 (10)	3.2 (0.125)	4.2 (0.165)	8.9 (0.350)	10.0 (0.400)

Source: From *Impacts Design Manual,* Aluminum Association, Inc., New York.

Wall Thickness

The minimum wall thickness that can be produced commercially varies with the diameter of the part and the material being extruded. Table 3.8.2 gives the minimum wall thickness for aluminum-based materials.

Threads and Undercuts

Threads and undercuts must be produced in secondary operations.

Double-Wall Shells

Double-wall shells can be produced without difficulty by incorporating a wide-diameter center tube. This center tube can be longer than the sidewalls and be open or closed at the top or bottom. Multiwall extruded parts also can be produced.

Asymmetrical Parts

Although it is preferable to design symmetrical parts, especially for the production of parts having large ratios of length to diameter, asymmetrical parts can be produced if the height is not too great. To produce such parts, however, it is necessary to secure a uniform flow of metal to all edges of the die by adjusting the tool angles. This process is strictly empirical and may be quite time-consuming.

Secondary Operations

Many parts produced by backward extrusion require only trimming to length. However, certain operations that may be required to finish a part cannot be performed

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during extrusion. These include heading, flanging, flaring the open end, ironing, drilling, threading, and forming undercuts. If possible, designs requiring these operations should be avoided.

DESIGN RECOMMENDATIONS FOR FORWARD EXTRUSION

Symmetry

Symmetrical shapes are preferred for forward extrusion.

Length-Diameter Ratio

The length of a part produced by forward extrusion is limited only by the size of the blank that can be handled and the ease of removal of the part from the die. Forward extrusions can be made with length-diameter ratios of 100:1 or greater.

Draft

It is possible to design for zero draft on the sidewalls.

Flanges

Flanges can be formed during forward extrusion. They can be heavy, stepped, or formed in a variety of shapes. The following suggestions will aid in attaining the easiest flow of the metal during extrusion:

1. The bottom corners of the part can be square and do not require a fillet where bottom and sidewall join. There should be a fillet, however, where the extrusion and the flange join. (See Fig. 3.8.12.)

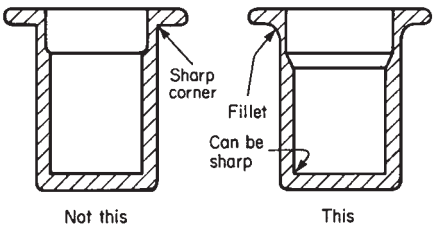

FIGURE 3.8.12 Forward extrusions should have a radius at the junction of a flange and the sidewall. Bottom corners, however, can be sharp.

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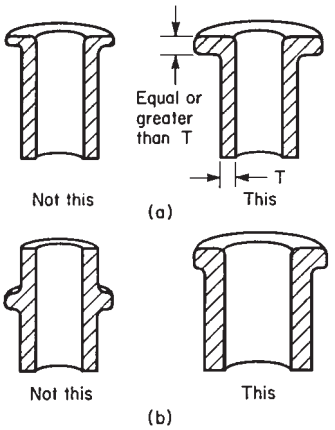

FIGURE 3.8.13 Flanges should be at least as thick as the sidewall (*a*) and be located at or near the ends of the forward extrusion (*b*).

2. Flanges should be symmetrical.
3. They should have thicknesses equal to or greater than the sidewall. (See Fig. 3.8.13*a*.)
4. They should be placed at the end of the part or close to the end. (See Fig. 3.8.13*b*.)
5. Diameters of flanges should be as small as possible.

Threads and Undercuts

As with backward extrusion, threads and undercuts must be produced by secondary operations.

DIMENSIONAL FACTORS AND TOLERANCES

Tolerances attainable in backward extrusion depend on such factors as tool wear, regularity of metal flow, size and shape of the part, wall thickness, and material being extruded. When thin-walled tubes are extruded, for example, tool wear will cause increases in the wall thickness of the shell and a corresponding reduction in its length. The thickness on the base is influenced by the lengthening of the punch by thermal expansion, and allowance must be made for this effect in setting tolerance limits. Tolerances attainable commercially also vary with the alloy.

Aluminum

Aluminum has been backward-extruded for many years, and tolerances that can be attained have been quite well established. Representative tolerances for round, square, and rectangular shells are indicated in Table 3.8.3.

Copper

Tolerances that can be maintained on small parts are

Wall thickness: ±0.08 mm (0.003 in)

Diameter: ±0.08 mm (0.003 in)

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TABLE 3.8.3 Typical Tolerances for Regular Shapes in Aluminum Alloys in Backward Extrusion

			Tolerances, ±mm (in)			
Outside dimensions, mm (in)	Wall thickness, mm (in)	Bottom thickness, mm (in)	Outside diameter	Inside diameter	Bottom	Length
Round shells						
6 (¼)	0.25–0.50 (0.010–0.020)	0.50–0.76 (0.020–0.030)	0.13 (0.005)	0.15 (0.006)	0.18 (0.007)	0.8 (1/32)
25 (1)	0.38–0.63 (0.015–0.025)	0.63–0.88 (0.025–0.035)	0.13 (0.005)	0.15 (0.006)	0.25 (0.010)	0.8 (1/32)
50 (2)	0.50–0.76 (0.020–0.030)	0.81–1.1 (0.032–0.042)	0.18 (0.007)	0.20 (0.008)	0.30 (0.012)	0.8 (1/32)
75 (3)	0.63–1.3 (0.025–0.050)	1.0–1.7 (0.040–0.065)	0.20 (0.008)	0.25 (0.010)	0.38 (0.015)	0.8 (1/32)
Square shells			Side	Side		
44×44 (1¾ × 1¾)	0.63 (0.025)	0.88 (0.035)	0.2 (0.008)	0.25 (0.010)	0.38 (0.015)	0.8 (1/32)
50×50 (2 × 2)	0.63 (0.025)	0.88 (0.035)	0.2 (0.008)	0.25 (0.010)	0.38 (0.015)	0.8 (1/32)
56×56 (2¼ × 2¼)	1.6 (0.062)	1.9 (0.075)	0.2 (0.008)	0.25 (0.010)	0.38 (0.015)	0.8 (1/32)
Rectangular shells			Side	Side		
50×25 (2 ×1)	0.63 (0.025)	0.88 (0.035)	0.2 (0.008)	0.25 (0.010)	0.38 (0.015)	0.8 (1/32)
64×56 (2½ × 2¼)	0.78 (0.025)	1.3 (0.050)	0.2 (0.008)	0.25 (0.010)	0.38 (0.015)	0.8 (1/32)

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IMPACT- OR COLD-EXTRUDED PARTS

TABLE 3.8.4 Typical Tolerances for Backward-Extruded Magnesium Parts

Dimension	Tolerances, ±
Diameter	0.2% of diameter
Bottom thickness	0.13 mm (0.005 in) for all sizes
Wall thickness, mm (in)	
0.50–0.75 (0.020–0.029)	0.05 mm (0.002 in)
0.76–1.12 (0.030–0.044)	0.08 mm (0.003 in)
1.13–1.50 (0.045–0.059)	0.1 mm (0.004 in)
1.51–2.50 (0.060–0.100)	0.13 mm (0.005 in)

Magnesium

Typical tolerances attainable in commercial production are given in Table 3.8.4.

Zinc

Tolerances that can be held on small parts are

Inside diameter: +0.00, −0.15 mm (+0.000, −0.006 in)

Outside diameter: ±0.08 to ±0.13 mm (±0.003 to ±0.005 in)

Wall thickness, 0.25 to 0.5 mm thick: ±0.08 mm (0.010 to 0.020 in thick: ±0.003 in)

Steels

Tolerances that can be met in commercial production are

Backward Extrusion

	Outside diameter, mm (in)	Inside diameter, mm (in)	Length, mm (in)
Small parts	±0.025 (0.001)	±0.1 (0.004)	±3 (0.12)
Large parts	± 0.4 (0.016)	±0.35 (0.014)	±6 (0.24)
Deviation of outside diameter from inside diameter: 0.5–1.2% of nominal OD Out-of-roundness: 0.2 to 0.6% of nominal OD			

Forward-Extruded Solid Parts

	Diameter, mm (in)
Small parts	±0.05 (0.002)
Large parts	± 0.13 (0.005)

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Surface Finish

The surface finish that can be attained on a backward-extruded part depends on the condition of the tools and the alloy being extruded. If tools are properly maintained, finishes as low as 0.8 μm (32 μ in) rms can be achieved. Finishes that are attained commercially on several materials are:

Aluminum	
1100	0.8–1.6 μm (32–63 μin)
6001	1.6 μm (63–250 μin)
7075	3.1–6.3 μm (125–250 μin)
Copper	1.6 μm (63 μin)
Steels	1.5–5.0 μm (60–200 μin)

As in backward extrusion, the surface finish attainable in forward extrusion depends on the condition of the tools. Surface finishes of 1 to 5 μm (40 to 200 μin) have been attained on aluminum in commercial operations; 1.5 to 5 μm (60 to 200 μin), on steel.

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